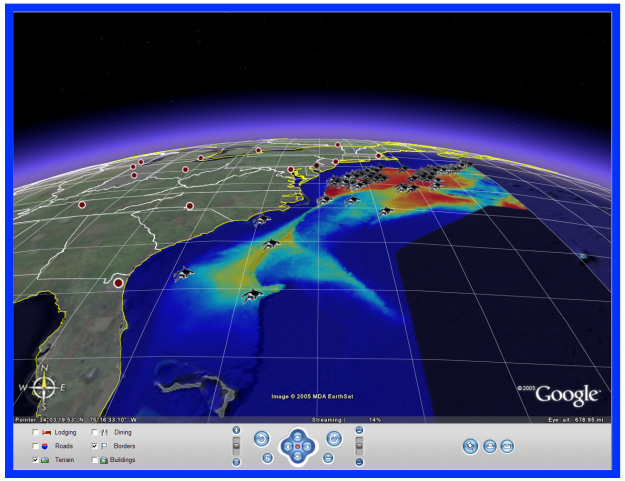
Phase I Discovery & Feasibility project* NNX11AR56G *:

Evaluating user needs for models and decision tools to predict the impacts of climate change on the marine environment



PI Pat Halpin, Duke University

NASA Grant / Cooperative Agreement NNX11AR56G

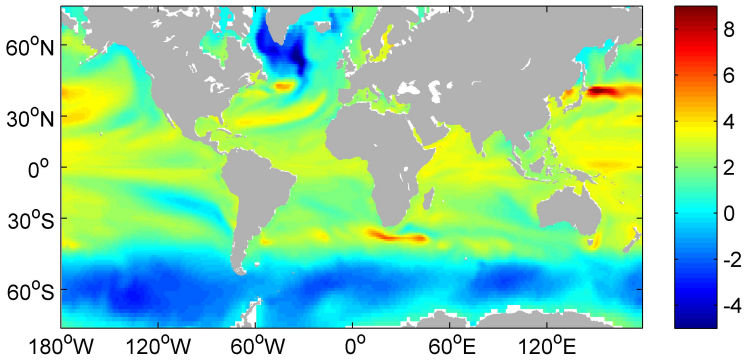
Marine Geospatial Ecology Lab, Nicholas School of the Environment, Duke University

Phase I Discovery & Feasibility project* NNX11AR56G *:

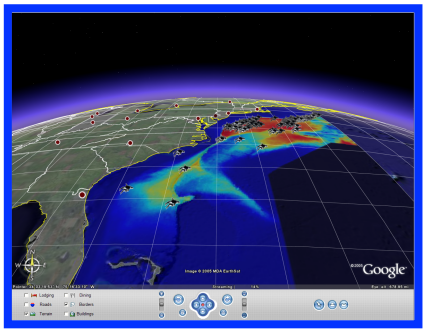
Evaluating user needs for models and decision tools to predict the impacts of climate change on the marine environment

Goal: explore the extension of marine animal forecasting DST to include long-term climate change capabilities:

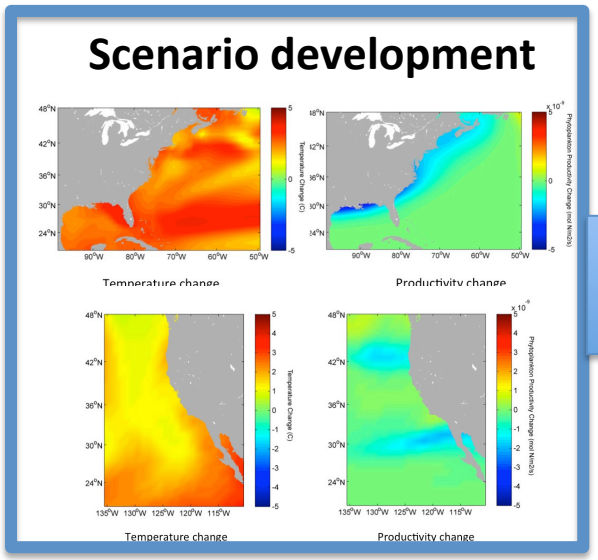
GFDL TOPAZ model



marine animal DST



ARL 0



interim progress

ARL 1

End-user webinars
Workshop

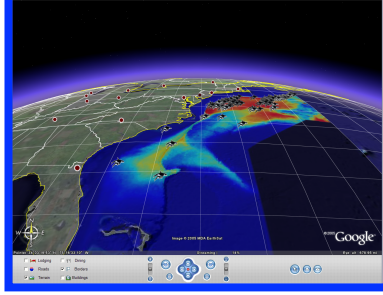
spring / summer 2013

ARL 2.3 – 3.1

Feasibility report

summer 2013

PI Pat Halpin, Duke University



Outline:

- Protected species forecasting problem
- Past / ongoing forecasting efforts
- Inclusion of climate change scenarios
- User needs assessment
- Next steps

Cetaceans (whales, dolphins and porpoises) and anthropogenic threats

Threats include

Ship strikes

Fishery bycatch

Naval activities

Anthropogenic sound

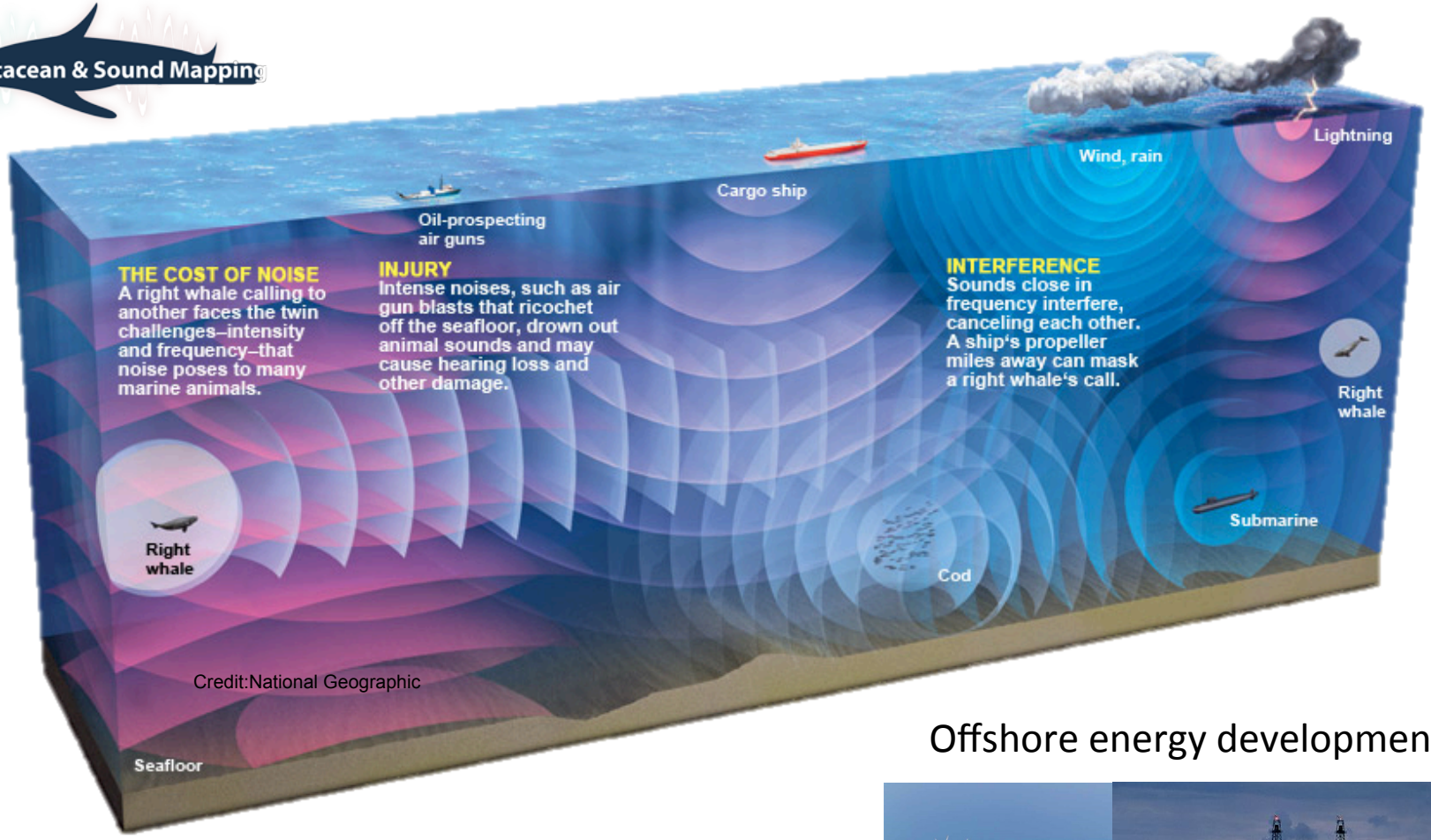
Cetaceans protected by US laws

MMPA

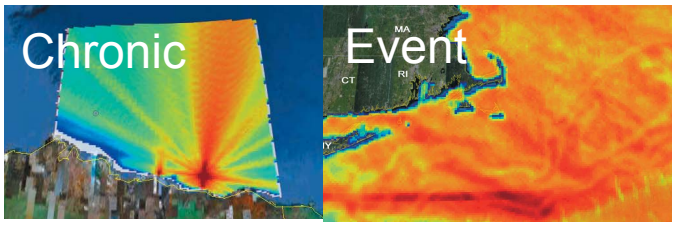
ESA

A special focus on acoustic habitats

Cetacean & Sound Mapping



Credit:National Geographic



Offshore energy development

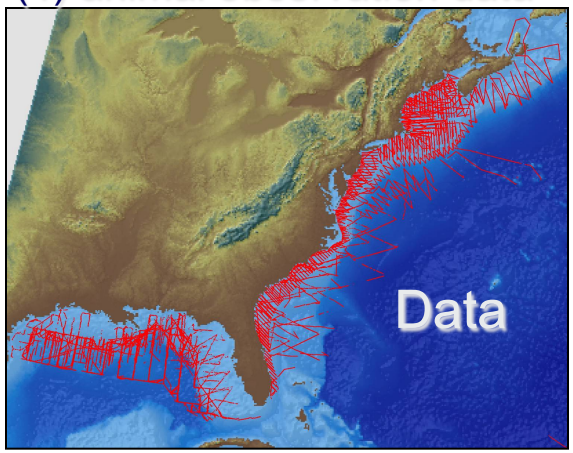
Cetaceans (whales, dolphins and porpoises) and anthropogenic threats

What are the potential changes in oceanographic conditions, marine animal distributions and densities that will effect future management of protected species?

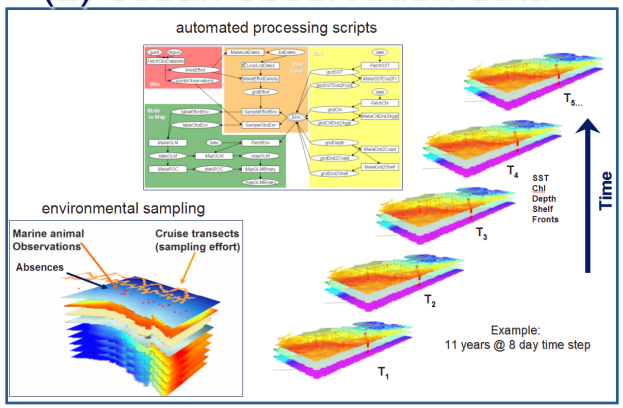
What are the data and forecasting needs of federal management agencies in the future?

Current Forecasting Process

(1) animal observation data

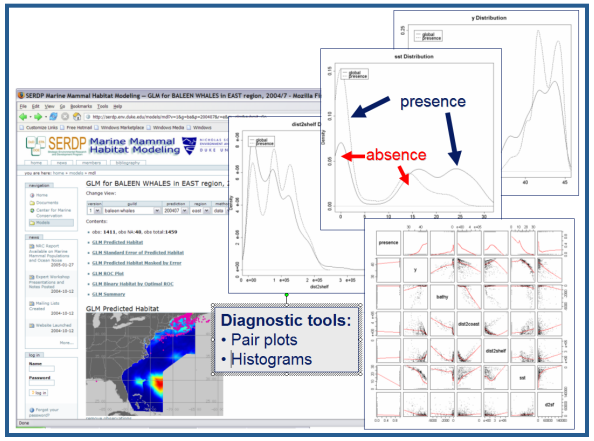


(2) ocean observation data



Temporally matched covariates

GAM models of density & habitat



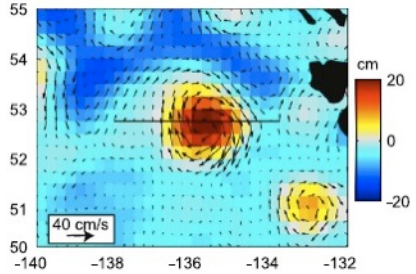
(3) statistical analysis & modeling

(4) spatial decision support system

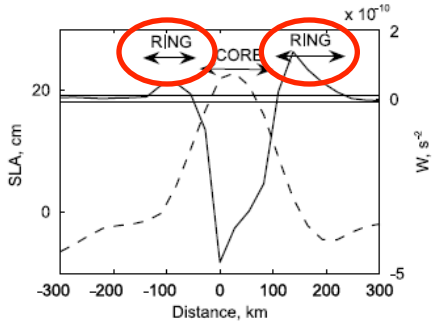
Dynamic Variables from Satellites

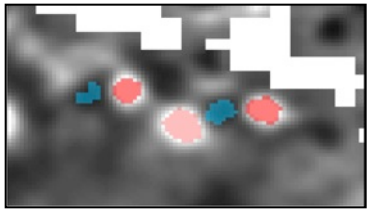
Eddies from AVISO

Isern-Fontanet et al (2006)



$$W = s_n^2 + s_s^2 - \omega^2,$$

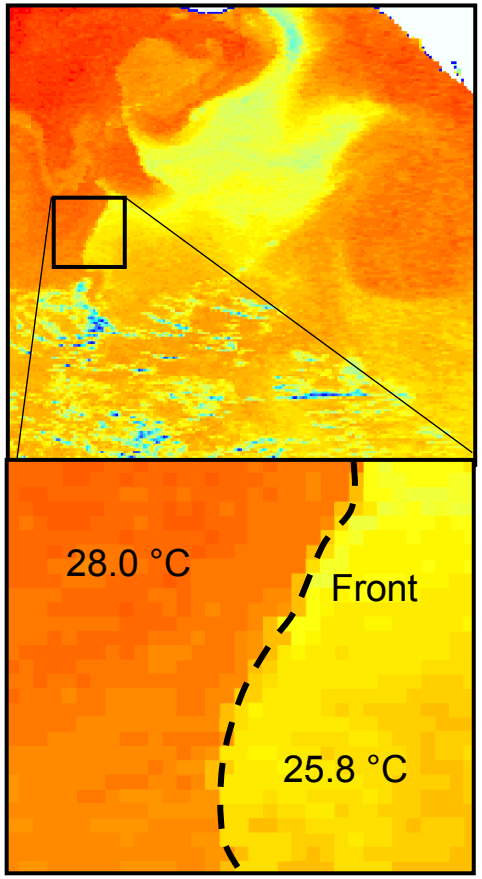


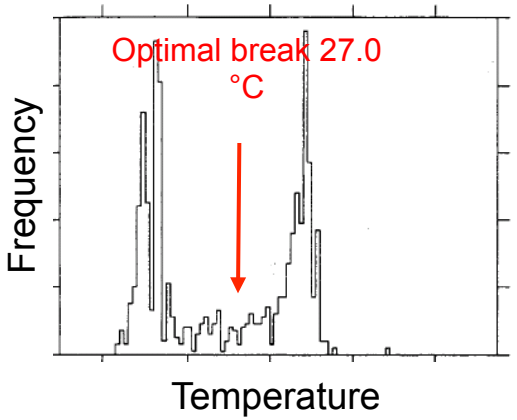


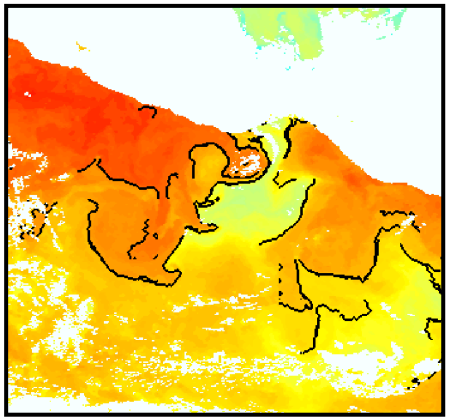
Red: Anticyclonic Blue: Cyclonic

Fronts from Pathfinder / GHRSST

Cayula, J-F and P Cornillon (1992)

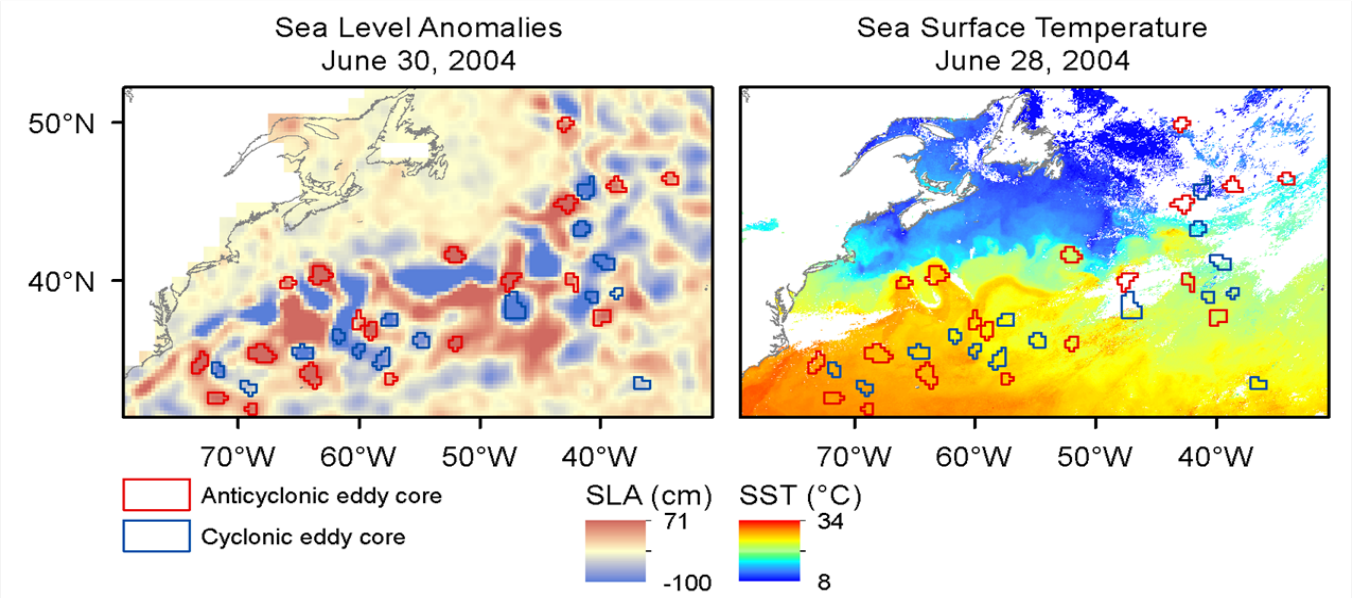




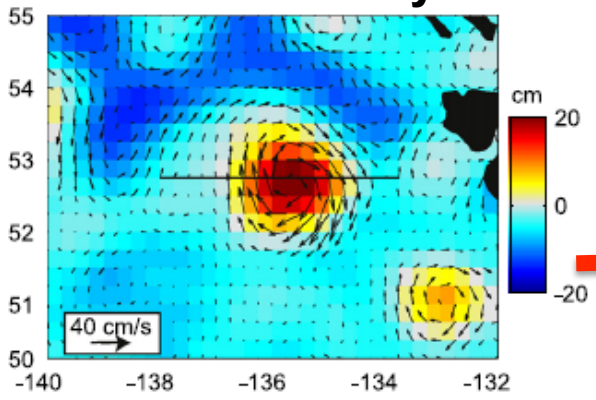


Previous NASA project NNX08AK73G goal: Upgrade DST to use more dynamic oceanographic covariates

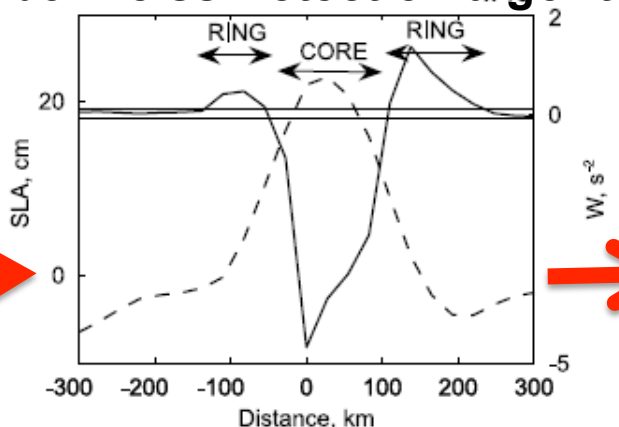
Detecting sea height anomalies & eddys



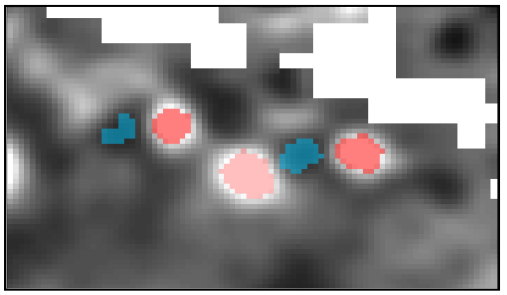
SSH anomaly



Okubo-Weiss Detection algorithm



Derived eddy features



Aviso DT-MSLA 27-Jan-1993
Red: Anticyclonic Blue: Cyclonic

Species data providers

Ocean data providers

NASA project enhancements

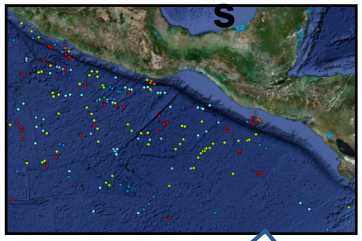
Protected Species Decision Support System

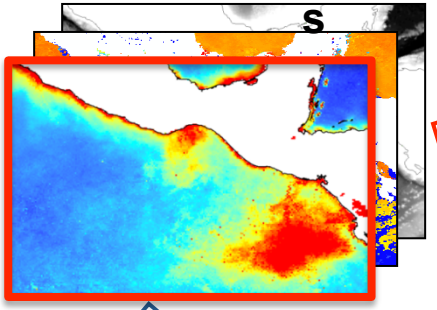
NASA project NNX08AK73G

Species observations

More

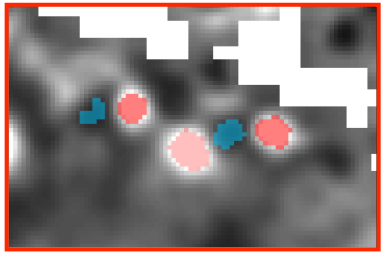
Ocean observations





Algorithms

$$u = -\frac{g}{f}\frac{\partial h}{\partial y}, \quad v = \frac{g}{f}\frac{\partial h}{\partial x}.$$
$$\omega = \frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}, \quad s_n = \frac{\partial u}{\partial x} - \frac{\partial v}{\partial y}, \quad s_s = \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}.$$
$$W = s_n^2 + s_s^2 - \omega^2,$$

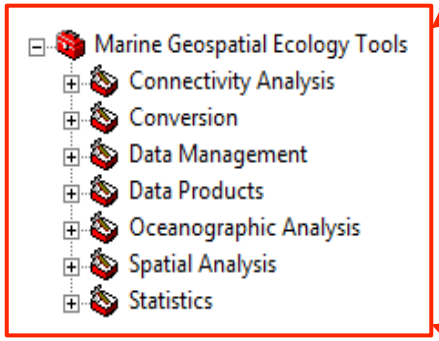


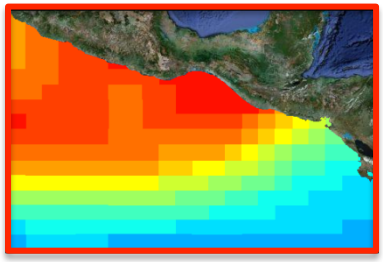
Statistical models

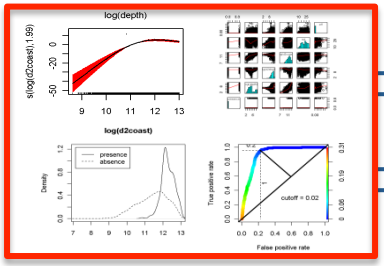
$$g(\mu) = \beta_0 + \beta_1 x_1 + \cdots + \beta_m x_m$$
$$g(\mathrm{E}(Y)) = \beta_0 + f_1(x_1) + f_2(x_2) + \ldots + f_m(x_m).$$

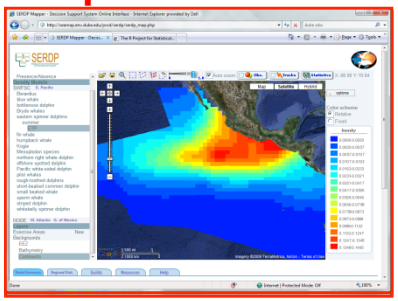
Ecologically-important parameters

GIS Tools







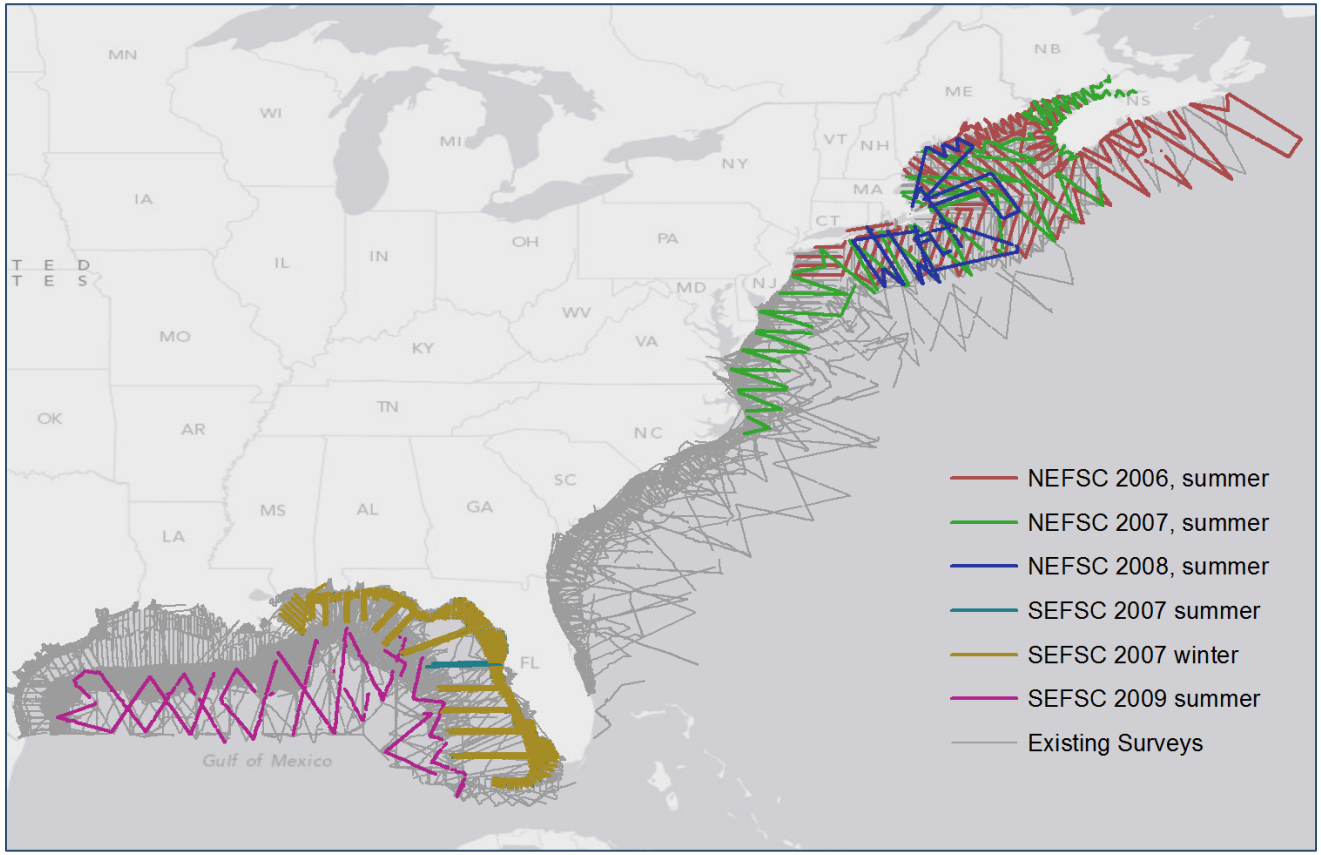


Predicted distributions

Summary plots

SDSS website

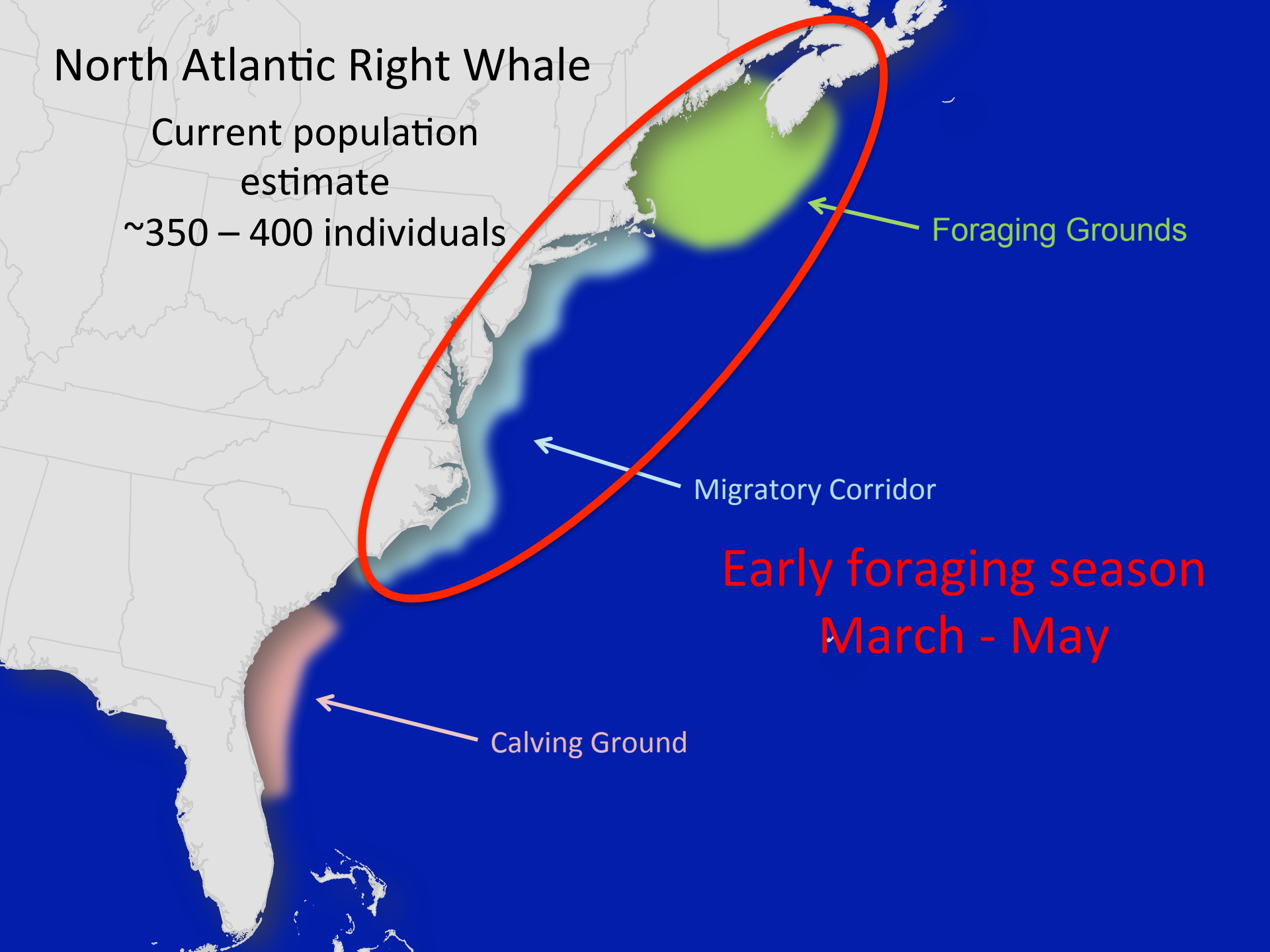
Ongoing updates of density models using new covariates



New Atlantic datasets now processed for producing updated cetacean density surface models.

New covariates

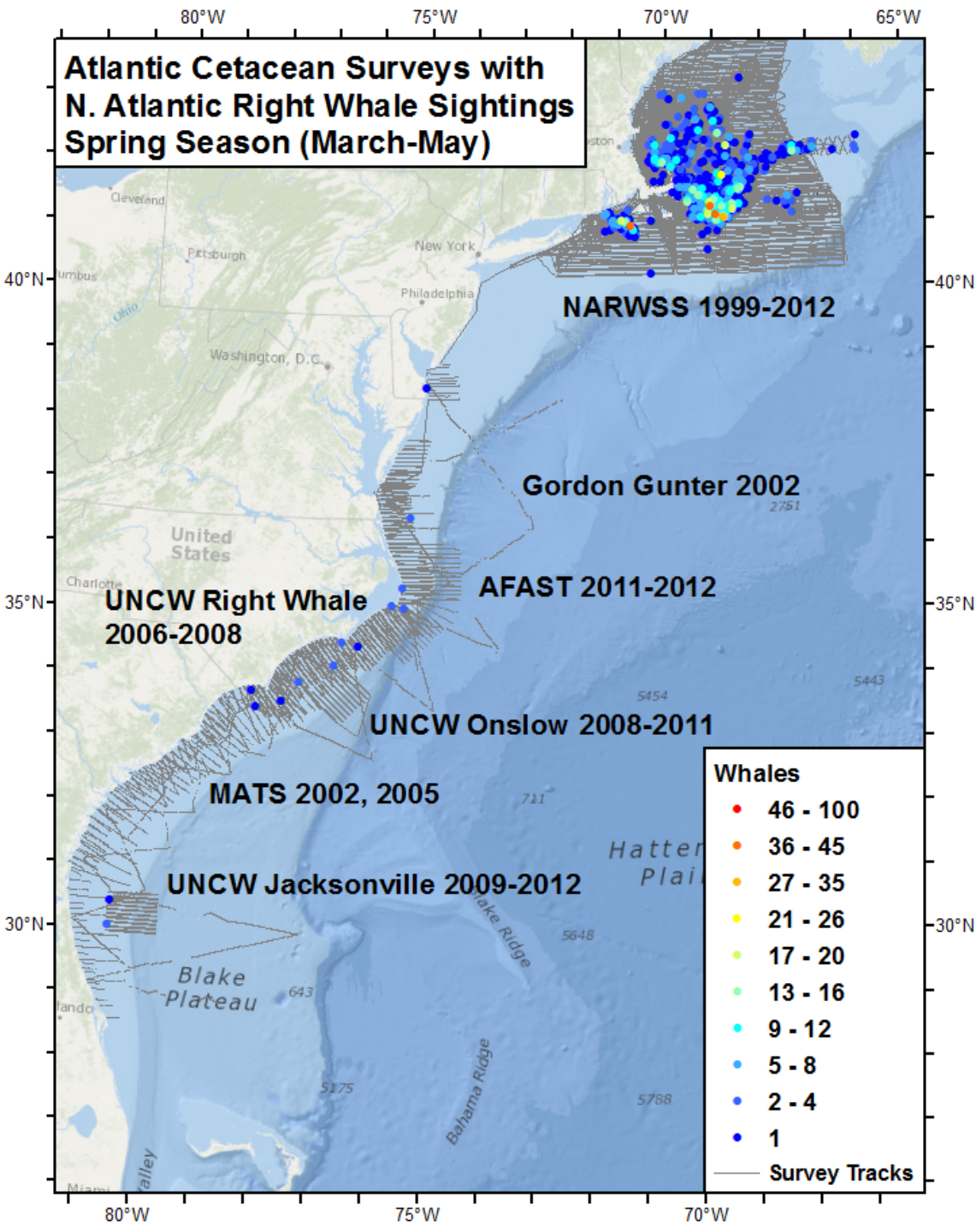
- Time of year as a circular statistic
- Oceanographic model outputs, including mixed layer depth
- Dynamics: fronts, eddies, Lagrangian coherent structures, EKE,…


North Atlantic Right Whale
Current population estimate
~350 – 400 individuals
Foraging Grounds
Migratory Corridor
Early foraging season
March - May
Calving Ground

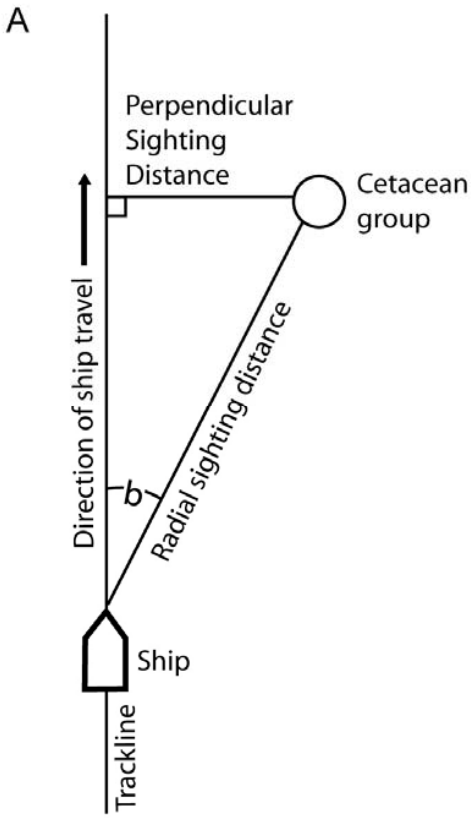
Survey data

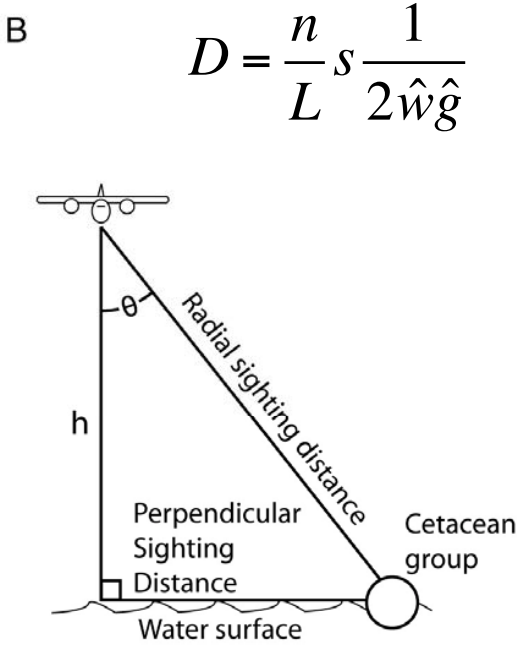
Survey records from 7 survey programs that operated between 1999-2012.

~287,000 km of linear distance surveyed during the focal spring season months of March-May



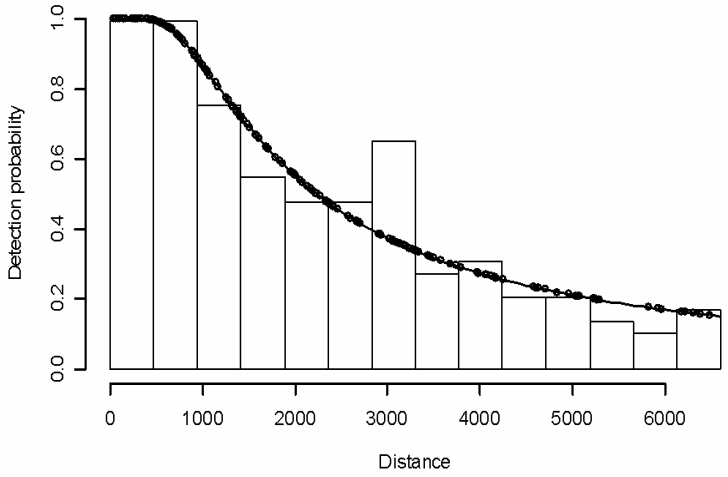
Density Estimation





$$D = \frac{n}{L} s \frac{1}{2\hat{w}\hat{g}}$$

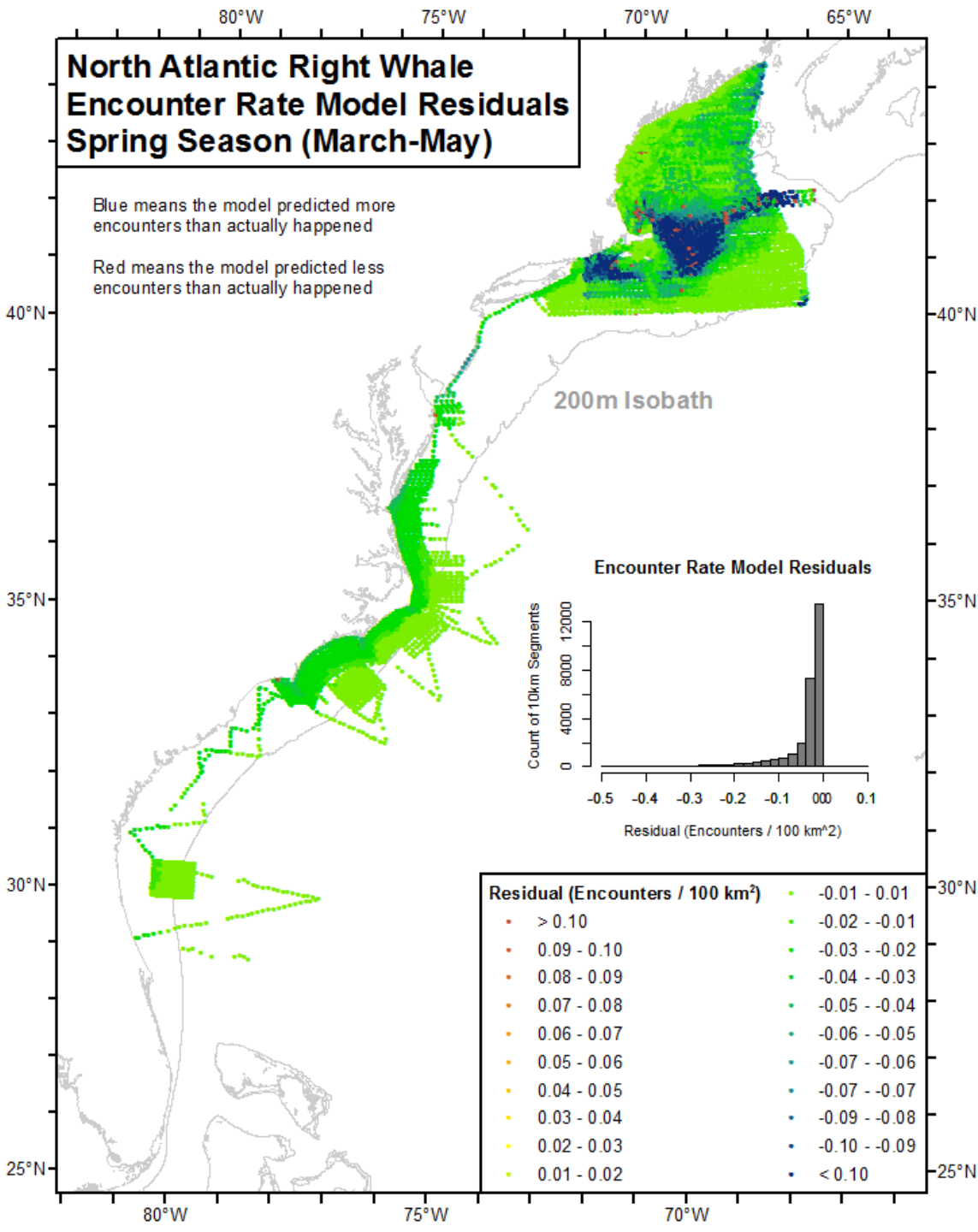
n: encounters
L: line length
s: school size
w: effective strip width, *p(distance)*
g: probability of detecting on line, *p(0)*



Encounter rate model

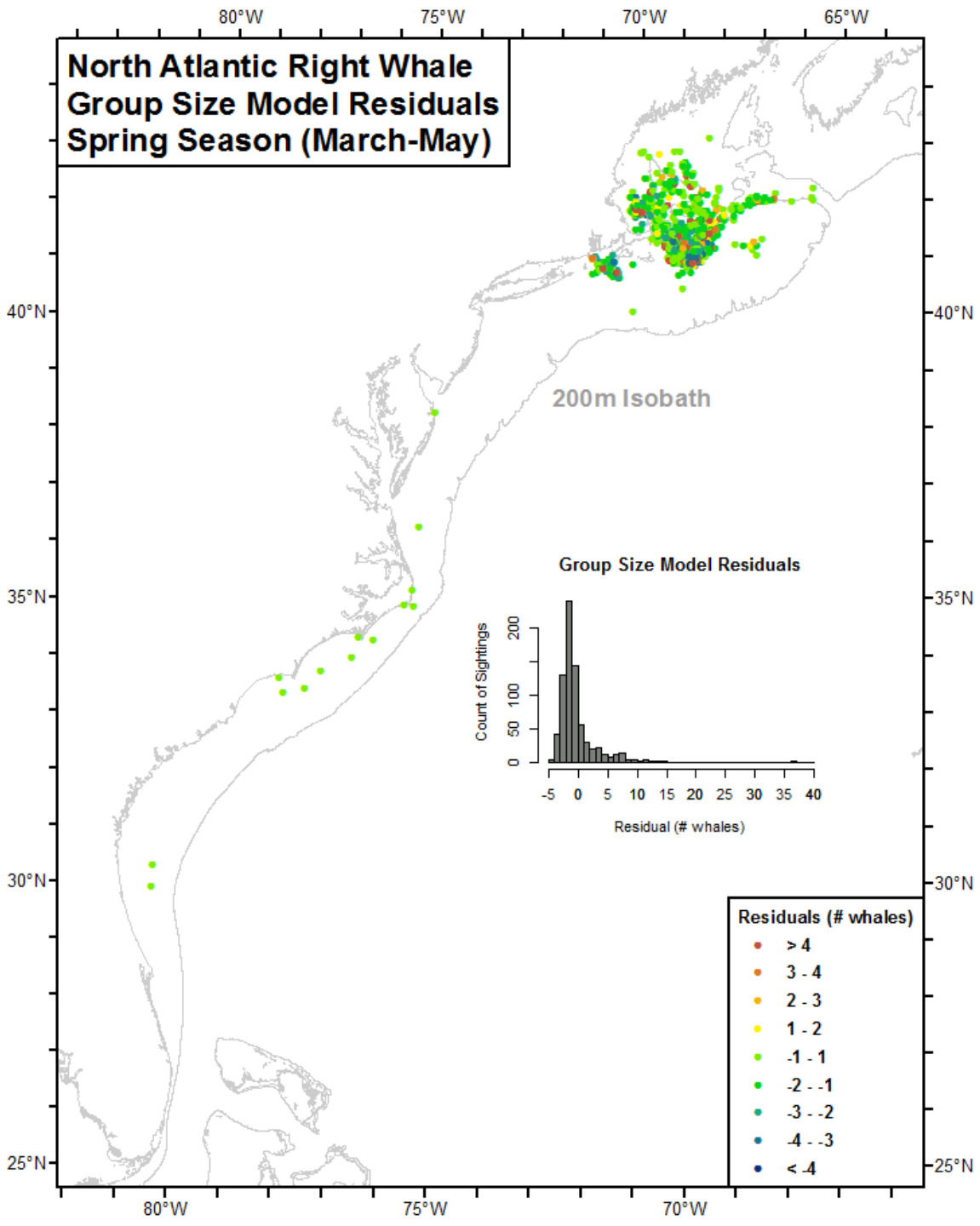
Question: how many animals are observed per sq km.

Must account for observer conditions and detection function.



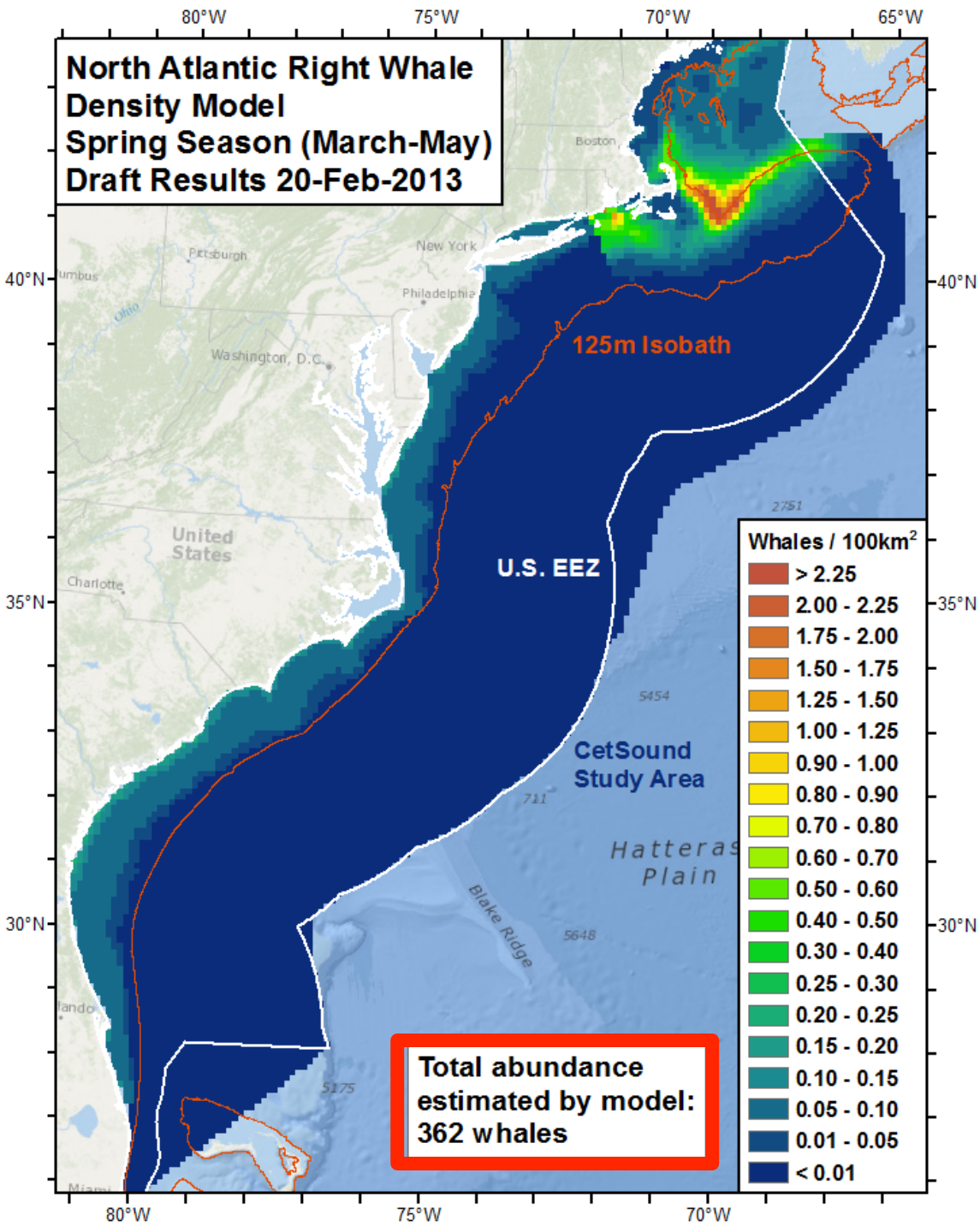
Group-size model

Question: how many animals are observed in each group

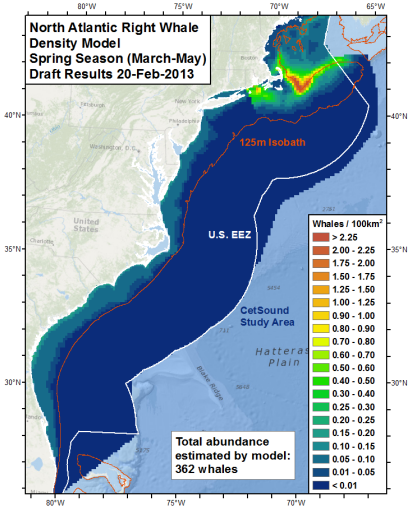


Density model

The total abundance of NARW is currently estimated to be 350 – 400 animals



Predictor variables used in spatial models



Static physiographic covariates:

- **Distance to shore**
- **Bathymetric slope**
- **Distance to closest 125m isobath**
- **Distance to closest 300m isobath** greater than 250 km in length

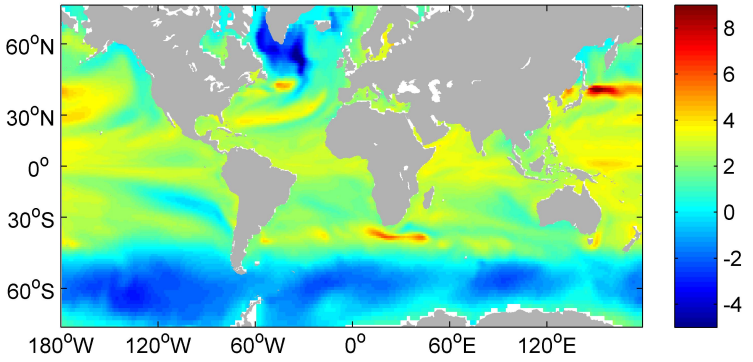
Climatological oceanographic covariates, computed on 8-day binning periods

- NOAA NODC AVHRR Pathfinder 5.2 **SST**
- UCSB GSM merged SeaWiFS/Aqua/MERIS **chlorophyll-a** concentration (Maritorena et al.)
- **Total kinetic energy (TKE)** from AVISO DT-MADT Upd daily geostrophic currents
- **Eddy kinetic energy (EKE)** from AVISO DT-MSLA Upd daily geostrophic currents
- **Distance to closest 1 °C SST front**, computed in AVHRR Pathfinder SST using the Cayula-Cornillon (1992) algorithm implemented in the Marine Geospatial Ecology Tools software (Roberts et al. 2010)

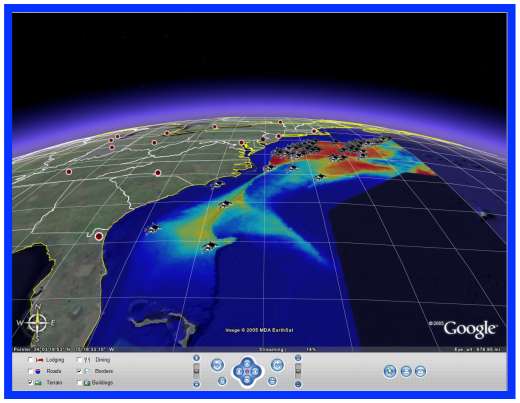
Hypothesis: Dynamic oceanographic covariates better represent features that aggregate copepod prey…

Future forecasting needs

GFDL TOPAZ model



Cetacean SDSS

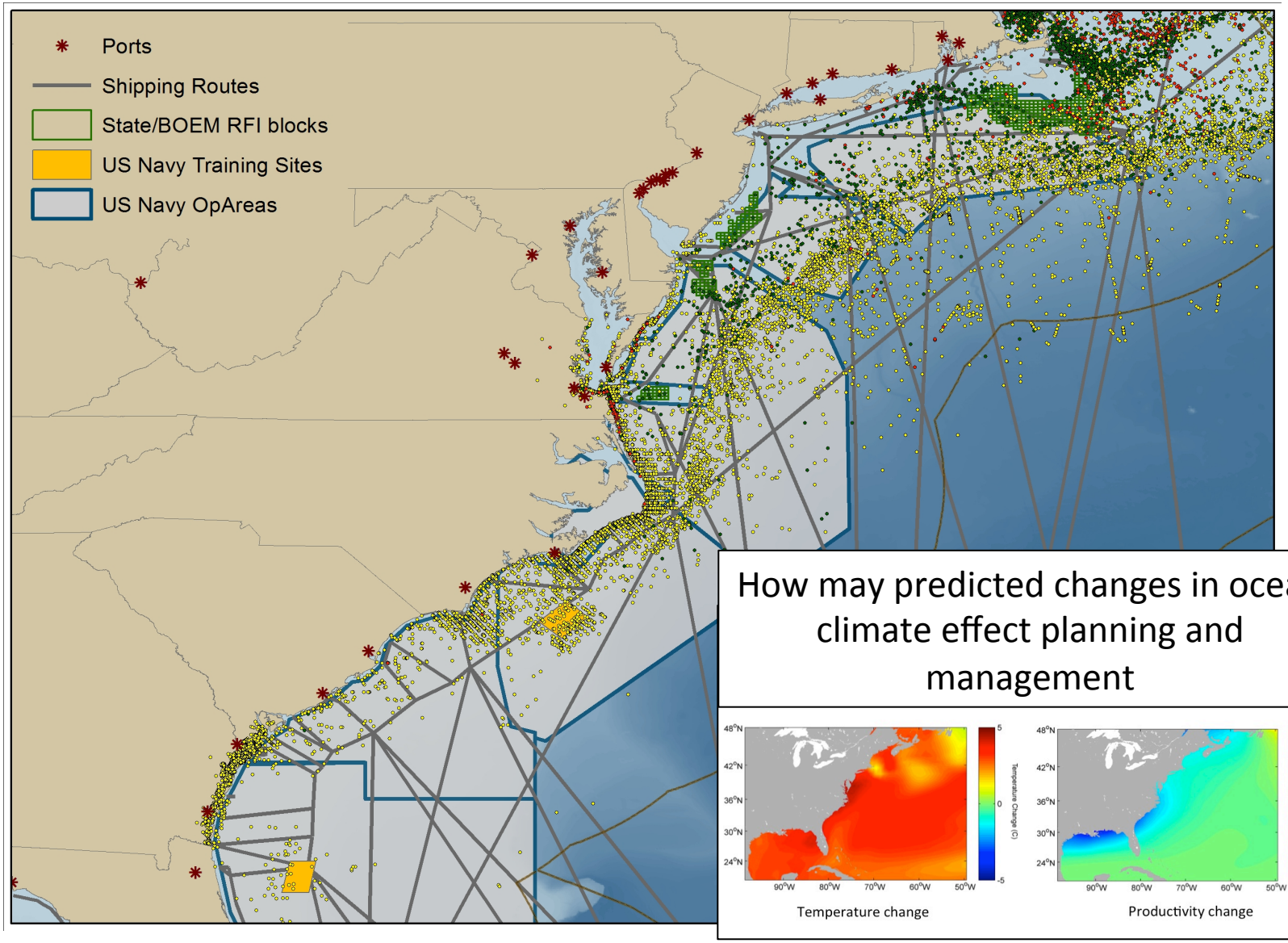


Research question: *What remote sensing and downscaling forecasting model products will federal agency users require for the management of migratory pelagic species under changing climates?*

Approach: A user needs evaluation for new models and decision support tools to forecast potential changes in marine environments and habitats under future climate change scenarios.

- Structured user needs questionnaires;
- A series of webinars and video meetings;
- An end-user workshop.

Cetacean observations, navy training areas, shipping channels and renewable energy lease blocks



Future forecasting needs

The primary questions are:

- how will responsible agencies and organizations use information on potential shifts in critical species habitats and densities;
- what types of forecasting information will be most useful to these users;
- what are the spatial, temporal and taxonomic resolutions required for long-term planning needs;
- how will end users use information on model forecast error and uncertainty;
- what data quality standards will end users require for forecast information.

Summary of work performed to date

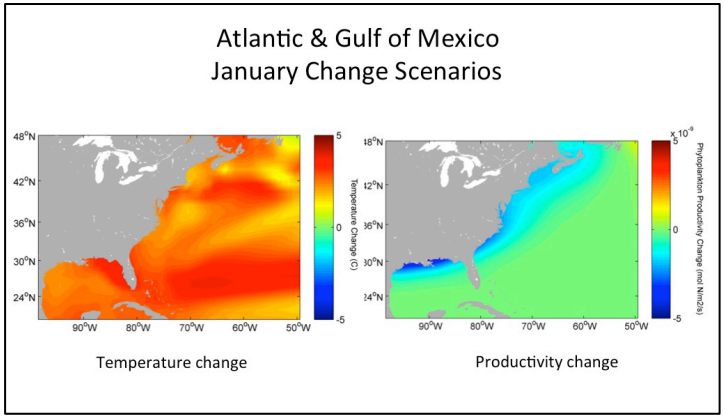
Our work to date has been in two areas:

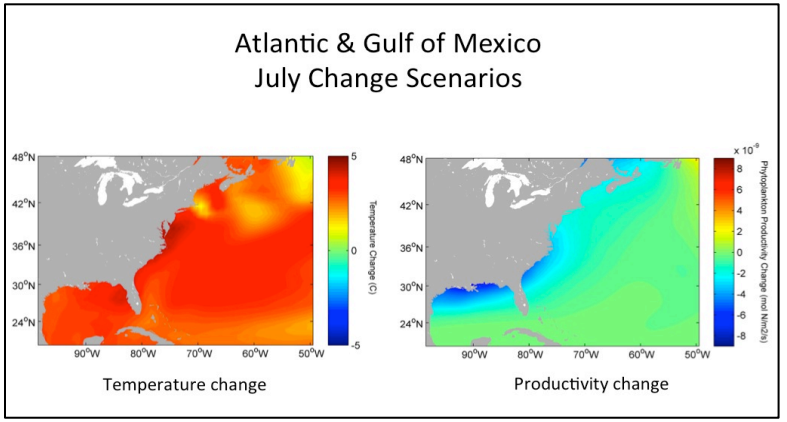
(1) We have been developing IPCC class oceanographic scenarios in preparation for our end-user engagement process; and

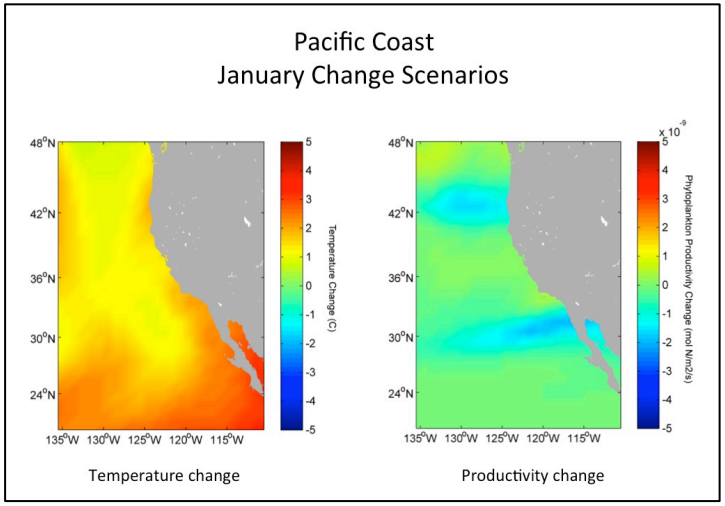
(2) Webinar and workshop planning and preparation.

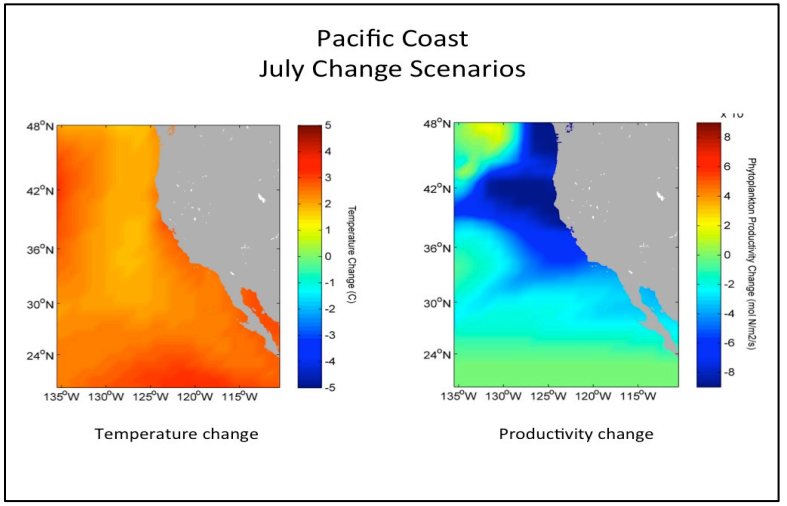
Future forecasting needs

(1) IPCC class oceanographic scenarios in preparation for our end-user engagement process;





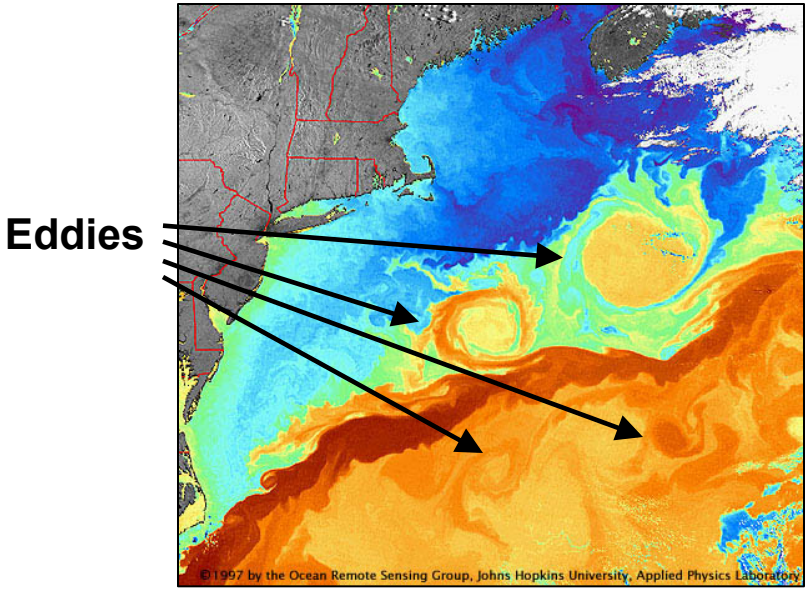




Potential extension: fisheries ecology

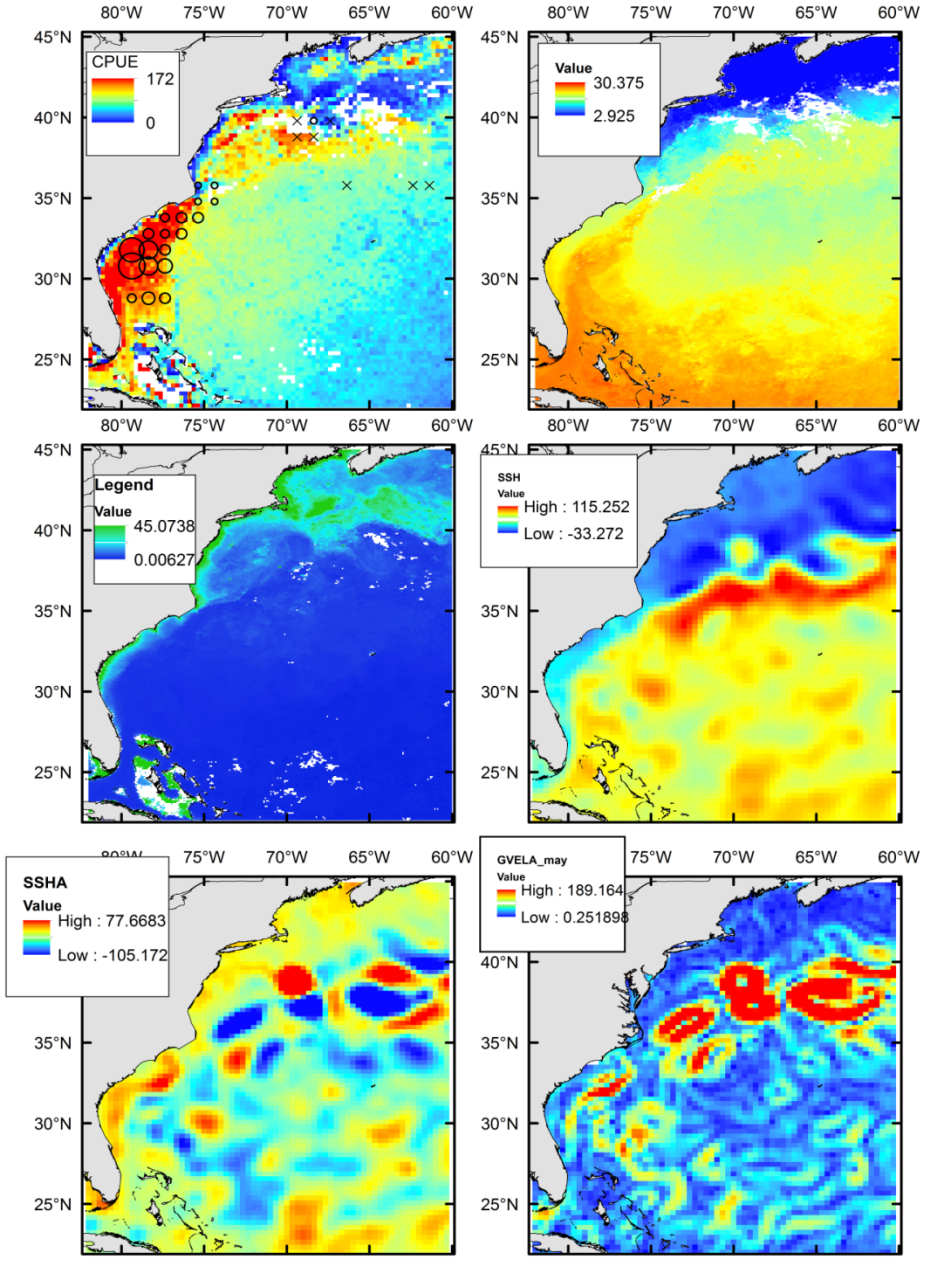
Example: Are tuna and swordfish catches in the northwest Atlantic correlated with eddies and how may these features change in the future?

What are the forecasting needs of fisheries managers?



Hsu, A, AM Boustany, JJ Roberts, and PN Halpin (submitted). Effects of mesoscale eddies on CPUE of four fish species in the western north Atlantic. *Fisheries Oceanography.*

Potential extension: fisheries ecology



What fisheries are related to “fixed” features and which fisheries are related to climatological features?

What are going to be the “sticky fish” under climate change scenarios…

Boustany, Dunn and Halpin 2013
AAAS Symposium

Future forecasting needs

(2) webinar and workshop planning and preparation.

We have also been conducting planning and materials for the webinars and user workshop to be conducted in spring / summer 2013.

We will provide background materials, scenarios and questionnaires to representative end users from NOAA, Navy, BOEM, USF&W, NASA and other agencies prior to deployment of the video webinar(s) and in-person workshop.

Future forecasting needs

(2) webinar and workshop planning and preparation.

The webinars are intended to be used to explore general user needs issues and scenarios prior to a workshop in order to better optimize the time spent for the in-person workshop session. Also: the webinars may be able to capture a broader audience of available participants.

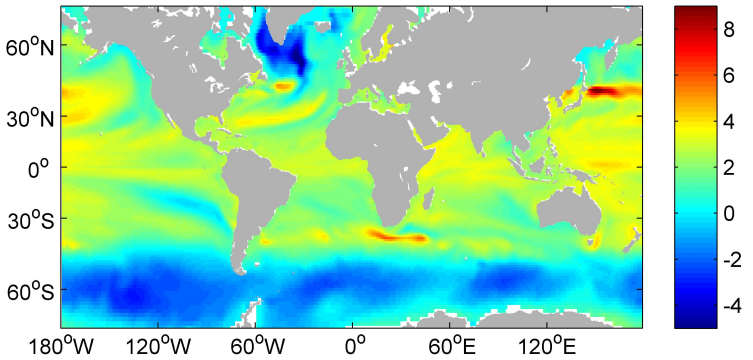
*(**Note:** due to the increased risk that government agency participants may have additional travel and budget restrictions in spring 2013, we are developing contingency plans for an increased reliance on webinar interactions in lieu of in-person meetings if needed.)*

Phase I Discovery & Feasibility project* NNX11AR56G *:

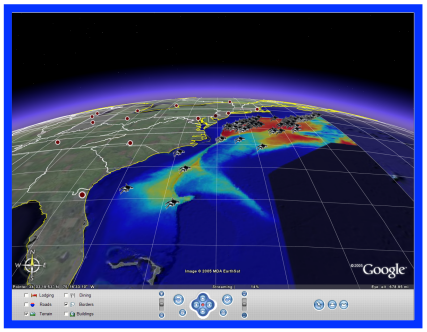
Evaluating user needs for models and decision tools to predict the impacts of climate change on the marine environment

Goal: explore the extension of marine animal forecasting DST to include long-term climate change capabilities:

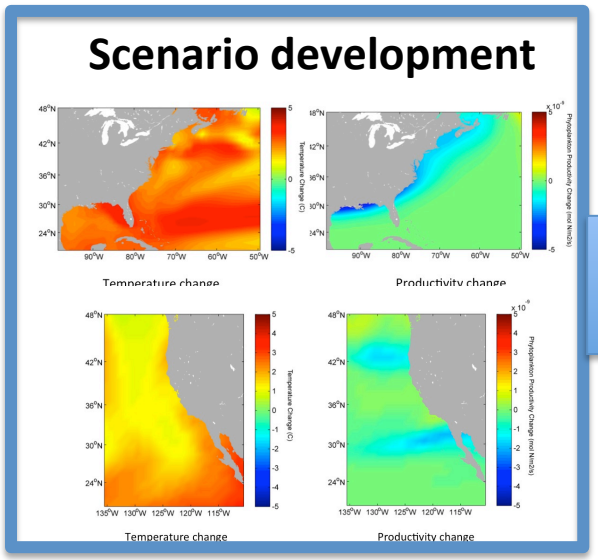
GFDL TOPAZ model



marine animal DST



ARL 0



interim progress

ARL 1

End-user webinars
Workshop

spring / summer 2013

ARL 2.3 – 3.1

Feasibility report

summer 2013

PI Pat Halpin, Duke University